OPPORTUNITIES AND CHALLENGES OF MANAGED AQUIFER RECHARGE (MAR) AT DROUGHT PRONE WATER STRESSED BARIND AREA, BANGLADESH

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ABSTRACT

The study aims to focus on the opportunities and challenges of Managed Aquifer Recharge (MAR) at the drought prone water stressed Barind area, north-west region of Bangladesh. Almost three crops are produced round the year as the area is mostly flood free. The lower amount of rainfall than country-wide average as well as less percolation capacity of thick top clay layer lies above the potential aquifer at higher depth put constraint for groundwater resource development. On the other hand due to low or no flow of water in the river and gradual extraction of groundwater for irrigation causes the declination of groundwater table which demands Managed Aquifer Recharge (MAR) for the area. The MAR technique, previously known as 'artificial recharge' - a water banking system is a viable adaptation menu for subsequent recovery, future use and environmental benefits. Major opportunities are about 2000 km re-excavated *Kharies* (canals) containing about 750 nos. check dam, more than 3000 re-excavated ponds, number of *Beels* (comparatively large marshes) and other water bodies which are used to conserve runoff storm water for supplementary irrigation for about 5-7 months. The conserved water can be used for the groundwater recharge alongside irrigation. Furthermore, roof-top rain water of the office and other buildings can also be used for groundwater recharge purposes. On the other hand, major challenges obtained through the study are the highly turbid runoff storm water, sedimentation of thick clay over the bed of the canal that restricts the natural percolation, failure of conventional direct surface methods of recharge due to the presence of more than 50 ft thick top clay layer from the ground surface which has low or no percolation capacity, lack of practical knowledge on artificial groundwater recharge (MAR) for the study area, clogging of conventional MAR technique due to deposition of silty clay on the top of recharge unit. Therefore, engineering and modified MAR structures are necessary to reverse the declining trend of groundwater level as well as to restore the groundwater resources for sustainable use.

Keywords: *Managed aquifer recharge, Recharge well, Groundwater, Challenges of MAR, Opportunities in Barind area*

1. INTRODUCTION

Water is one of the most important resources on earth but its distribution on the Earth's surface is extremely uneven. Only 3% of water on the surface is fresh; the remaining 97% resides in the ocean. Of freshwater, 69% resides in glaciers, 30% underground, and less than 1% is located in lakes, rivers, and swamps. Furthermore, only one percent of the water on the Earth’s surface is usable by humans, and 99% of the usable quantity is situated underground (Bralower and Bice, 2012). Water scarcity is the lack of fresh water resources to meet water demand that affects every continent and was listed in 2019 by the World Economic Forum as one of the largest global risks in terms of potential impact over the next decade (WEF, 2019). One-third of the global population (2 billion people) live under conditions of severe water scarcity at least 1 month of the year. Half a billion people in the world face severe water scarcity all year round. Half of the world’s largest cities experience water scarcity (WEF, 2020).

Barind tract is the most drought prone water scarce area in Bangladesh. It is a physiographic unit located in the north-western part of Bangladesh having gross area of 7,727 sq km (Rasheed, 2008). Geographically this unit lies between 24˚20'N and 25˚35'N latitudes and 88˚20'E and 89˚30'E longitudes. Barind Tract made up of Pleistocene Alluvium is also known as Older Alluvium and floored by reddish, brown, sticky Pleistocene sediment, Madhupur Clay (Ahmed, 2006). The hard red soil, typical dry climate with comparatively high temperature and less rainfall of these areas are very significant in comparison to that of the other parts of the country (BMDA, 2018). Temperature varies from 8 degrees Celsius to 44 degrees Celsius (Ahmeduzzaman, et al., 2012). Averages annual rainfall ranges from minimum 1250 mm to maximum 2000 mm and almost 80% of the rainfall occurs during June to October (IWM, 2012). Storm water is the only source of groundwater recharge as the area is flood free (IWM, 2012; Rahman, 2012). But the storm water cannot percolate easily due to top clay layer more than 15 m thick and low infiltration capacity (2-3 mm/day) (Jahan, 2010a) cause reduction of the natural recharging of groundwater (Jahan, 2015).

Due to scarcity of surface water and less rainfall, cultivation as well as irrigation of the area has become dependent on groundwater (GW). GW irrigation was started in 1985 through Barind Integrated Area Development Project (BIADP) under Bangladesh Agricultural Development Corporation (BADC). More than 15000 Deep Tube wells (DTW) have been installed in the north-west region by BMDA, BADC and private initiatives. The DTWs and Shallow Tube Wells (STW) are always engaged to withdraw groundwater for irrigation excessively and due to the over exploitation groundwater table (GWT) is going down day by day (CGWB, 2000; Bhattacharya, 2010). Due to excessive withdrawal of groundwater for irrigation, less rainfall, high temperature, low natural recharge and low flow in the major rivers in the dry season, ground water level has been falling all over the region (Imon and Ahmed, 2013). Rahman and Mahbub (2012) also observed the depletion of groundwater level in the Tanore Upazilla of the srudy area.

Continuous depletion of GWT may pose serious impact on the environment. To reverse the declining trend of GWT and to increase groundwater storage Managed Aquifer Recharge (MAR) is essential for the study area. Therefore, the aim of this study is to identify the challenges and opportunities for the augmentation of groundwater by managed aquifer recharge technique.

2. METHODOLOGY

2.1 Study area

The study area lies at godagari, tanore, nachole and niamatpur upazila under rajshahi, chapai nawabgonj and naogaon districts of barind area respectively which is shown as figure 1.

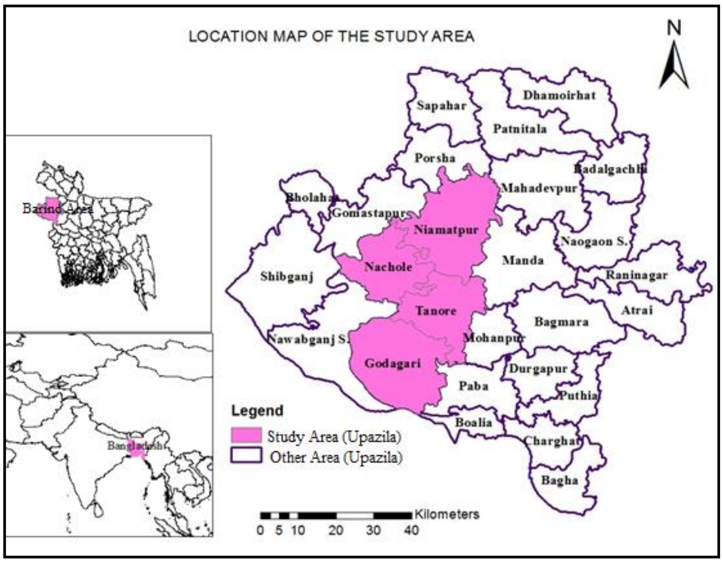

Figure 1: Location map of the study area

2.2 Data collection

To assess the challenges of MAR techniques, Rainfall and Groundwater level data, lithological information have been collected from the BMDA. Information about surface water quality, sedimentation on the canal bed as well as the clogging of top layer of the MAR unit by the silty clay has also been observed. All the data and information are checked for quality and consistency and then processed in the required format. On the other hand, to find out the opportunities of MAR technique, the information about re-excavated Khal/Kharies (canal), constructed cross dam (check dam) in the re-excavated Kharies, re-excavated ponds, Beels (comparatively large water body) and other water bodies has been collected from the zonal office of Barind Multipurpose Development Authority (BMDA). Information about office buildings has also been collected for roof top rain water harvesting and groundwater recharge.

3. FINDINGS AND DISCUSSIONS

The challenges and opportunities for the augmentation of groundwater through managed aquifer recharge stechnique in study area under Barind tract were identified based on field investigation and secondary data collected from different sources. The findings are presented with discussion in the following sections.

3.1 Challenges

The challenges those were identified in the study area are less rainfall, thick top clay layer, depletion of groundwater level, highly turbid storm water, sedimentation on cannel bed, clogging of conventional groundwater recharge well, less flow of river water and lack of practical knowledge. These challenges are elaborately discussed in the nest sections.

3.1.1 Less rainfall

Though rainfall is the main source of groundwater recharge but less and uneven distribution of rainfall is one of the main challenges of the study area for adoption of MAR techniques. The Table 1 shows that the 16 years average rainfall of the study area is 1340.56 mm which is much less than the annual average of the country (2500 mm) rainfall.

Table 1: Annual average rainfall of the Study area

Year	Annual average rainfall (mm)			
	Godagari upazila	Tanore upazila	Niamatpur upazila	Nachole upazila
2002	914.00	1756.57	928.00	1932.00
2003	869.00	1400.00	1014.00	1591.75
2004	2451.90	1632.00	904.25	1187.00
2005	1110.40	1607.00	1259.00	1141.00
2006	1290.12	1889.01	1087.81	1616.00
2007	1390.44	1790.00	1591.00	2029.00
2008	1401.10	2241.00	2295.00	1195.10
2009	932.00	1048.00	1310.00	1228.00
2010	1208.00	917.50	1262.00	987.00
2011	1440.00	1311.50	1537.00	1496.00
2012	904.00	1106.50	906.00	742.00
2013	885.00	1087.00	886.00	943.00
2014	848.00	1321.50	1631.00	1224.00
2015	1715.50	1405.00	1565.00	1740.00
2016	1025.00	1231.00	1884.00	1065.00
2017	1155.00	1248.00	1756.00	1332.00
Upazila ave.	1221.22	1436.97	1363.50	1340.55
Study area ave.	1340.56			

From Table 1 it is clear that this small amount of rain water is almost evenly occured over the different upazilas of the study area. It is obvious that a part of this small available rain water will be lost by evaporation during runoff and also from depressed land where it might accumulate if it is not possible to utilize properly. Therefore, appropriate technology is required for the proper management to attain the maximum benefit from it.

3.1.2 Thick top clay layer

For the collection of lithological characteristics of the study area sub-soil investigation in four upazilas under study area was carried out. The lithological information of four upazilas are presented as borelog in Figure 2.

The sub-soil investigation in the study area was performed up to the depth varying from 56 m to 75 m basically for the collection of lithological characteristics of the study area. The lithological bore logs show that the top layer of each location is composed of clay and it is varying from 20 m to 30 m. The highest clay layer of 30 m was found in Godagari upazila under Rajshahi district folowed by 24 m in Nachole upazila under Chapai Nawabgonj district, 21 m in Niamatpur upazila under Naogaon district and 20 m in Tanore upazila under Rajshahi district. This top thick clay layer restricts the percolation of water as well as natural recharge of groundwater. So, surface systems of mar technique would not be suitable and modification of recharge system should be adopted for groundwater recharge in the study area.

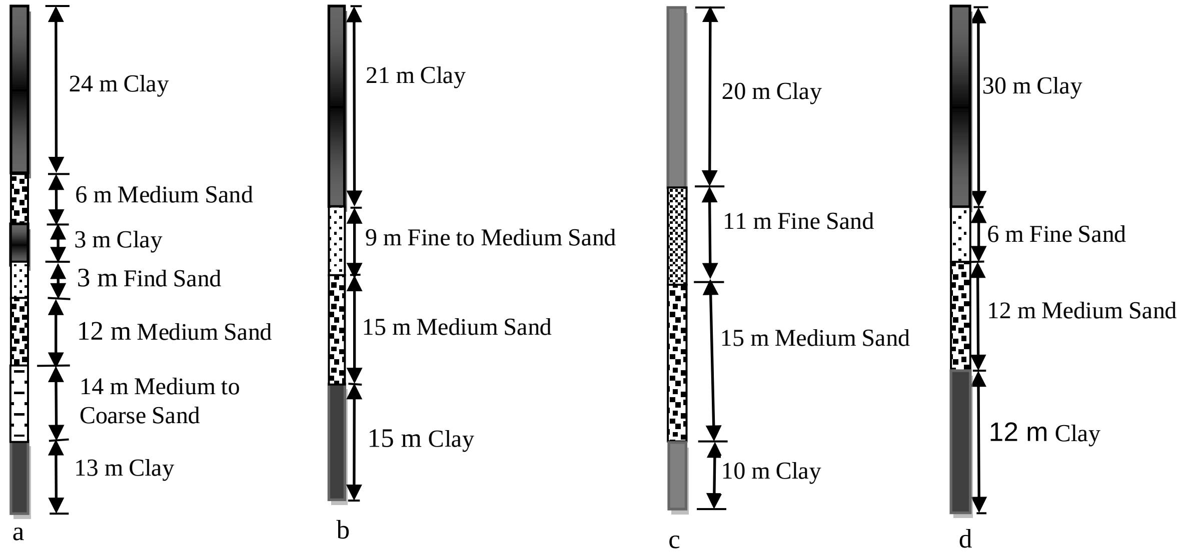

Figure 2: Bore log lithology- (a) plot no.-437, mouza-Muradpur-2, j.l. No- 148, upazila- Nachole, district- Chapai Nawabgonj; (b) plot no.-768, mouza- Nimdighi, j.l. No.- 151, upazila- Niamatpur, district-Naogaon; (c) plot no.-261, mouza-Aira- 2, j.l. No- 67, upazila- Tanore, district- Rajshahi; (d) plot no.-113, mouza- Amtoli, j.l. No- 195, upazila- Godagari, district- Rajshahi.

3.1.3 Depletion of groundwater level (GWL)

Groundwater level (GWL) of the study area is getting depleted day by day. So it is another challenge for the study area. Groundwater level records of 1st and 2nd half of January, April, July and October for the period from 1995 to 2018 are plotted on the curve for four upazilas within the study area are presented in Figure 3 to 6. Gradual declination of GWL is observed in all the upazilas of the study area.

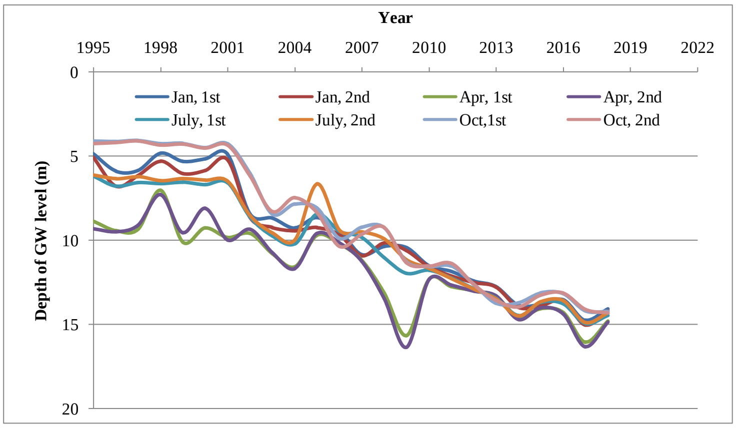

Figure 3: GWL Hydrograph at Haripur, Tanore upazila

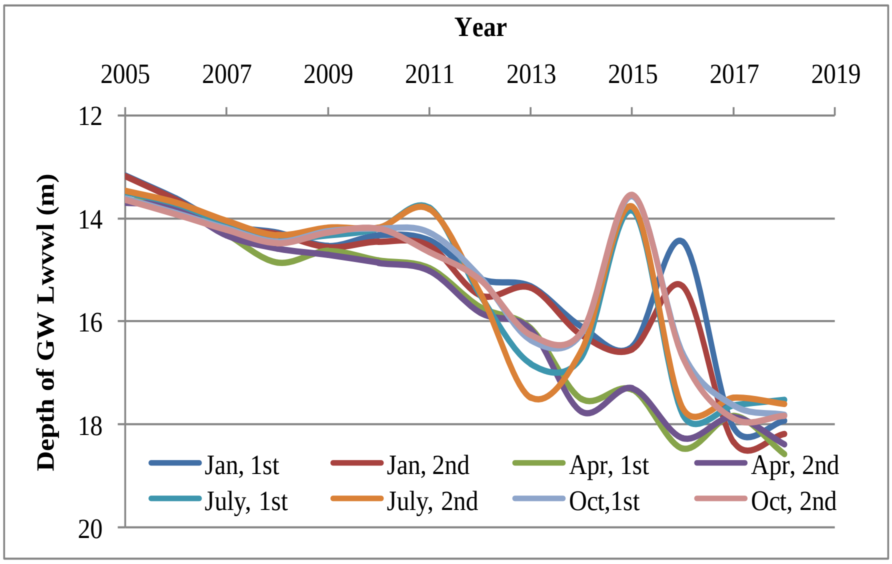

Figure 4: GWL Hydrograph at Darajpur, Niamatpur upazila

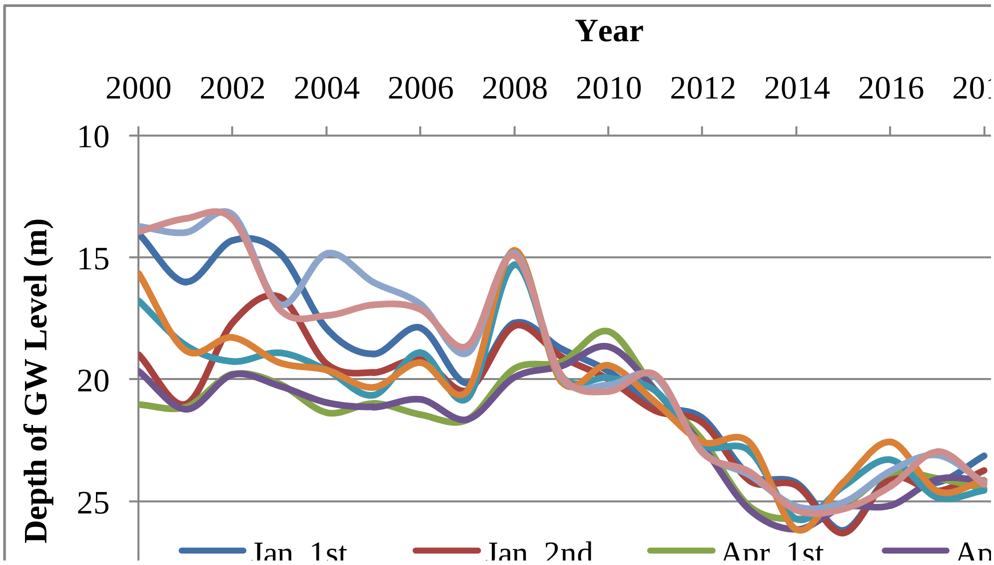

Figure 5: GWL Hydrograph at Amtoli-1, Godagari upazila

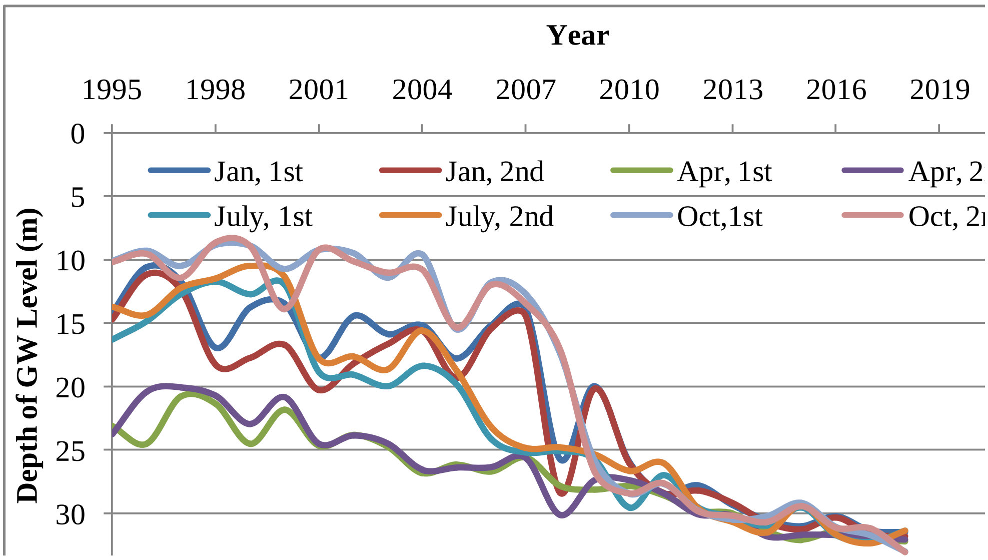

Figure 6: GWL Hydrograph at Ratipur, Nachole upazila

GWT generally goes down to the maximum depth in the month of April and goes up (gets back) to the minimum depth in the month of October. The highest depletion of groundwater varying among the upazilas from 17 m to 32 m from the ground surface. But gradual declination of groundwater level is found from the figures. To reverse the declining trend of GWL, appropriate MAR technique needs to be applied.

3.1.4 Sedimentation on the canal bed and clogging of RW

Conventional recharge well was constructed on the bed of canal for recharging groundwater during the monsoon. During the monsoon rainwater accumulated in the existing canal by surface runoff flows through. Runoff water storage facility was already built by constructing cross dam across the canal. It was thought that it could be the potential sources for recharging groundwater during the monsoon through conventional recharge well. However, it was found that sedimentation of clay materials from the turbid water on the bed of the canal as well as on the top surface of recharge well was observed. As a result, natural recharge of GW gets stopped totally and recharge rate of conventional MAR technique installed at the canal bed gradually decreases and clogging of top layer of recharge unit was occurred (Hossain, 2019). M.I. Hossain et al. (2019) mentioned that 40 mm to 80 mm thick muddy silt layer formed on the top surface of recharge unit and canal bed when canal was completely dried up. So, to overcome this challenge modified MAR technique along with filtration unit is needed for continuous and sustainable function. Figure 7 shows the clogging of conventional recharge technique and sedimentation of canal bed.

Figure 7: Clogged RW along with silted Canal bed at Godagari

3.1.5 Highly turbid runoff storm water

The canal water (surface water) of the study area was tested in different times in the laboratory of BMDA. The tested results are shown in Table 2.

Table 2: Turbidity value for the tested sample of surface water (*Khari* water)

Name of *Khari* (Canal)	Date of Testing	Turbidity (NTU)	Comments
Sharmangla, Godagari	02.04.14	400	As per the environmental conservation rule (ECR, 1997), the allowable limit for the turbidity of drinking water is 10 NTU.
	15.07.15	79	
	13.07.16	57	
	17.05.17	30	
	25.06.18	80	
Rasulpur, Niamatpur	15.07.13	68	As per drinking water standard (ECR, 1997), turbidity value will be within 10 NTU
	30.06.14	48	
	15.07.16	30	
	20.07.17	20	
	25.06.18	20	
	03.09.18	80	

The storm runoff water of the canal is highly turbid. The turbidity of Sharmangla canal varies from 30 to 400 NTU while turbidity varies in Rasulpur canal from 20 to 80 NTU that are extremely higher than that of the acceptable limit of 10 NTU. Turbidity of water is the main cause of clogging the recharge unit. For sustainable recharge of groundwater suitable filtration unit needs to be developed with RW.

3.1.6 Low flow of water in rivers

Low water flow in rivers is another challenge of the study area. In dry season water level in the rivers of the study area goes down to the bed causes very low or no flow. Due to the low water stage than GWL of the nearby aquifer causes movement of groundwater from the aquifer to the river making declination of GWL with steep sloppy toward river. Average yearly water loss from Barind across the Ganges is 13.45 Mm^3/year and from Barind across the Indian border is 7.24 Mm^3/year (IWM, 2006). So, for successful application of MAR technique, required depth of water in the river needs to be maintained.

3.1.7 Lack of practical knowledge

To get a satisfactory result on any initiative, it is necessary to have both theoretical and practical knowledge. Though MAR is not a new technology in the world but very few works have been performed in Bangladesh limiting to use of rooftop rain water only. Besides, lack of knowledgeable and experienced persons on this issue is also a problem. So to make the MAR technique a success especially in case of using runoff storm water as well as surface water, collective effort of experts, experiments in both in fields and laboratories are needed. Special training and practical visit of such type of works performed in other countries are essential.

3.2 Potential Opportunities

3.2.1 Re-excavated Kharies with cross dam (check dam)

Derelict Kharies (canals) are generally re-excavated by BMDA to increase their water conserving capacity. Cross dams are constructed in the re-excavated Kharies at different positions maintaining the certain gradient to retain the storm water. These re-excavated Kharies are used to conserve runoff storm water mainly for supplementary irrigation. In the study area there are 514 km of re-excavated Khari and 285 nos. of cross dam. And about 2000 km re-excavated Khari with 749 nos cross dam are there in the entire Barind area (BMDA, 2018). A remarkable portion of conserved water at the upstream of the cross dam can be used for groundwater recharge purpose by applying proper MAR technique. Re-excavated Kharis with RCC cross dam and rubber dam are shown in Figure 8.

Figure 8: The re-excavated (a) Sarmaongla Khari with a cross dam under Godagari upazila and (b) a rubber dam at the Barnoi river under Puthia upazila of Rajshahi district

3.2.2 Re-excavated Ponds

About 1248 nos of ponds have been re-excavated in the study area, while 3098 nos re-excavated ponds (BMDA, 2018) are there in the whole barind area. A significant portion of the conserved water in those ponds can be used for groundwater recharge with proper MAR structure alongside supplementary irrigation. The Figure 9 shows two re-excavated pond at Niamatpur upazila and Porsha upazila.

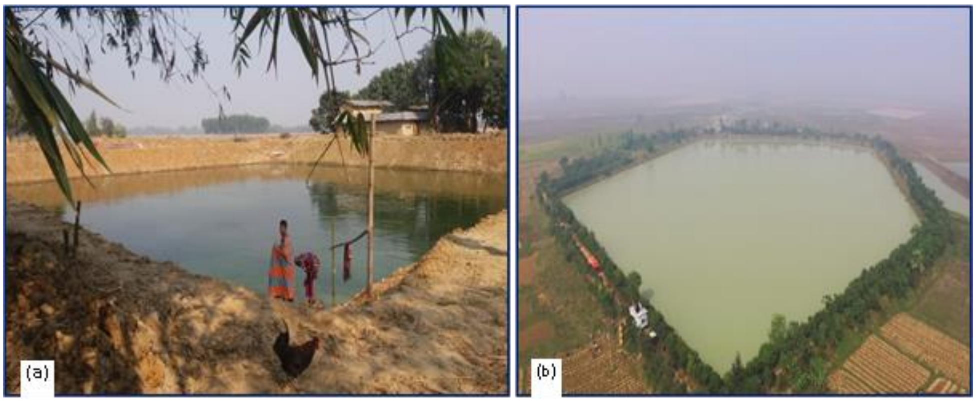

Figure 9: Re-excavated ponds- (a) Konnyapara (Re-excavated area 1.09 acre), Niamatpur, (b) Kushumkunda (Re-excavated area 17 acre), Porsha

3.2.3 Natural Beel

There are a significant number of Beels (comparatively large water body) in Barind area of which 5 nos. are in the study area. The names of those Beels in the study area are Beel Choroi, Durlar Beel (Godagatri upzila), Beel Kumari (Tanore upazila), Beel Kasba (Nachole upazila) and Chatra Beel (Niamatpur Upazila). Beels are generally located at the lower elevation where runoff storm water comes from the surroundings and storm water accumulated there. The Beels can be re-excavated to conserve more water and use for groundwater recharge using MAR technology. Figure 10 shows a natural Beel at Tanore upazila.

Figure 10: Beel Kumari beel at Tanore upazila under Rajshahi district

3.2.4 Roofs of the Office Buildings and Training Shed

At every upazila, BMDA and other Departments as well as organizations have their office buildings and training sheds/buildings within a well planned compound. Roof of these building in a close compound can be used as potential catchment for collecting the storm water. Rain water received by these buildings/sheds during rainfall can be accumulated through a common network and used for groundwater recharge through MAR technique like Recharge Well (RW) along with proper filtration unit.

4. CONCLUSIONS

Desert like drought prone barind area with less rainfall and thick top clay layer demands MAR techniques to recover the groundwater level as well as to restore groundwater as a water bank for the use in crucial period. Though there are significant number of opportunities like re-excavated canal with cross dam and rubber dam, ponds, Beels and roof top catchment to harvest rain water and groundwater recharge but lots of challenges like less rainfall, thick top clay materials, depletion of GWL, water turbidity and clogging are also the barriers to implement the MAR technique successfully. Also proper depth of water in the surrounding rivers including Ganges, Mohanonda, Atrai needs to be maintained for effective application of MAR technologies. Practical knowledge and collective efforts and pilot study program are also needed for reviving the Barind area making groundwater available with proper designed and modified MAR techniques.

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